Army Research Laboratory

# Visual Detection of Land Mines

by Kristin M. Schweitzer and Andrew S. Bodenhamer

ARL-TR-4073 April 2007

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**ARL-TR-4073** **April 2007**

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**Human Research & Engineering Directorate, ARL**

# REPORT DOCUMENTATION PAGE

*Form Approved*
*OMB No. 0704-0188*



| 1. REPORT DATE (*DD-MM-YYYY*) | 2. REPORT TYPE | 3. DATES COVERED (From - To) |
|---|---|---|
| April 2007 | Final | July 2006 |

**4. TITLE AND SUBTITLE**
Visual Detection of Land Mines

**5a. CONTRACT NUMBER**

**5b. GRANT NUMBER**

**5c. PROGRAM ELEMENT NUMBER**

**6. AUTHOR(S)**
Kristin M. Schweitzer and Andrew S. Bodenhamer (both of ARL)

**5d. PROJECT NUMBER**
62716AH70

**5e. TASK NUMBER**

**5f. WORK UNIT NUMBER**

**7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)**
U.S. Army Research Laboratory
Human Research & Engineering Directorate
Aberdeen Proving Ground, MD 21005-5425

**8. PERFORMING ORGANIZATION REPORT NUMBER**
ARL-TR-4073

**9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)**

**10. SPONSOR/MONITOR'S ACRONYM(S)**

**11. SPONSOR/MONITOR'S REPORT NUMBERS**

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
Approved for public release; distribution is unlimited.

**13. SUPPLEMENTARY NOTES**

**14. ABSTRACT**
The objective of this study was to identify indicators that enable the visual location of buried land mines. Four trained visual combat trackers each searched four 15-meter-long mine training lanes for visual indicators of buried mine simulants. Each mine simulant at the Fort Leonard Wood, Missouri, site gave some visual indicator that caused a tracker to mark it as a mine. Indicators included sub-strata stones, color changes, surface cracks, depressions, mounds, circular patterns (cracks, bare spots, vegetation, soil composition, etc.), disturbances, unnatural ledges or soil wash-outs, and recurring plant species over targets. The authors recommend teaching visual land mine detection to combat engineers, visual trackers, and any one who will be in possible land mine-contaminated areas. The authors also recommend that further research be conducted to broaden the visual indicator knowledge base to encompass different terrains and environments, various burying methods, and seasonal changes. As a direct result of this study, teaching of visual land mine detection has already been implemented at the U.S. Army Combat Tracking School at Fort Huachuca, Arizona.

**15. SUBJECT TERMS**
indicators; land mines; tracking; visual detection

| 16. SECURITY CLASSIFICATION OF: | | | 17. LIMITATION OF ABSTRACT | 18. NUMBER OF PAGES | 19a. NAME OF RESPONSIBLE PERSON |
|---|---|---|---|---|---|
| a. REPORT | b. ABSTRACT | c. THIS PAGE | | | Kristin M. Schweitzer |
| UNCLASSIFIED | UNCLASSIFIED | UNCLASSIFIED | SAR | 40 | 19b. TELEPHONE NUMBER (*Include area code*) (573) 329-8706 |

**Standard Form 298 (Rev. 8/98)**
**Prescribed by ANSI Std. Z39.18**

# Contents

## List of Figures



## List of Tables

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# 1. Introduction

When an object is buried in the ground, the soil and surrounding environment are disturbed in a way that cannot be completely erased. A careful study of the ground characteristics can reveal a multitude of indicators that provide evidence as to what happened to the soil (Tactical Tracking Operations School, 2006).

Selected U.S. Army combat engineers are taught to operate metal and mine detectors and to pinpoint a target. Searching for visual indicators of land mine emplacement is an aspect that is often neglected during metal and mine detector training. Soldiers often become so focused on the functionality of the machine that they appear to completely neglect any visual cues on the ground. (Davison & Schweitzer, 2004-2005). Visual trackers, on the other hand, are trained to find indicators and disturbances on the ground and to determine their tactical significance. Trackers operate in combat environments and are trained to search for trip wires and booby traps but are not typically taught the visual detection cues attributable to the land mine itself (Tactical Tracking Operations School, 2006).

The objective of this study was to use proficient visual trackers as subject matter experts to identify visual indicators that will ultimately be used to train Soldiers to visually detect buried land mines.

# 2. Method

This was a feasibility study that captured qualitative data such as participant comments and researcher observations of visual detection methods, along with recorded video data from an eye-tracking system.

## 2.1 Literature Review

The authors were not aware of any previous studies that identified visual indicators of buried land mines. A literature review revealed a few, very brief references (e.g., “visual detection was used”), which generally described north Africa during World War II or Vietnam, and a couple of references to Desert Storm. From the literature review, it was obvious that visual detection is an extremely important skill that is the primary method for identifying explosive hazards and booby traps (Eberharter, 1996; Schneck, 1993). It was also clear that specific information about indicators and what they represent was scarce.

## 2.2 Participants

The four participants for this study were volunteers who had successfully completed visual combat tracking training. Three of the participants were Soldiers (one captain and two sergeants first class) who completed 2 weeks of training at the U.S. Army Combat Tracking School at Fort Huachuca, Arizona. At the time of the study, two of the Soldiers were instructors for the combat tracking course, and all three Soldiers participated in periodic training exercises with the military police to maintain their skills. The fourth participant was a Department of Army contractor and was the head instructor for the Combat Tracking School. He had more than 30 years of visual combat tracking experience in addition to instructing military and law enforcement and was widely regarded as an expert in visual tracking.

Participants' ages ranged from 36 to 65 years, with a median age of 40. Three of the participants were male and one was female. Only one of the participants had ever received any training specifically about mines. The training occurred 7 years before the study and covered the visual recognition of markers, signs, depressions, and built-up areas (i.e., general indicators of a mined area, not specific indicators of mine emplacement). This same participant was in an operational environment (Bosnia/Kosovo) for 9 months.

All four participants were combat trackers whose primary duties had nothing to do with land mines. Their broad ranges of experience brought valuable input to the study through the diverse points of view used to identify indicators.

The intent of visual detection is to supplement current mine detection procedures, to assist in identifying potentially mined areas, and to possibly contribute to humanitarian efforts. Safety precautions would be the same as those for the primary activity that the Soldier was performing.

The voluntary, fully informed consent of the persons used in this research was obtained as required by 32 Code of Federal Regulations 219 and Army Regulation (AR) 70-25. The investigators have adhered to the policies for the protection of human subjects as prescribed in AR 70-25.

## 2.3 Apparatus and Materials

The inert land mine simulants that the participants attempted to identify were buried before this study (as described in section 2.4) and were not disturbed through the course of the study. Apparatus and materials used in the study included a training survey (see appendix A), colored poker chips (white, blue, and red), and Applied Science Laboratories' MobileEye system.

The mine simulants characterized a range of eight different land mine sizes. The smallest target represented an antipersonnel (AP) low metal (LM) mine and was approximately 2.4 inches in diameter. The largest target represented an antitank (AT) high metal (M) mine and was approximately 12.5 inches in diameter. The simulants are described in table 1.

Table 1. Description of mine simulants.

| Mine Simulant | Diameter (inches) | Simulant Type |
|---|---|---|
| Sim 6 | 2.36 | APLM |
| Sim 9 | 3.54 | |
| Sim 12 | 4.72 | |
| M15 | 12.5 | ATM |
| M16 | 3.00 | APM |
| Sim 20 | 7.87 | ATLM |
| Sim 25 | 9.84 | |
| Sim 30 | 11.81 | |

MobileEye is a spectacle-mounted eye tracking unit that includes a scenic camera to record the environment observed by the wearer, and an eye camera to record the eye being tracked. Three near-infrared lights reflect off the cornea and then are correlated with pupil movement to establish eye position. The unit includes a microphone for voice recording.

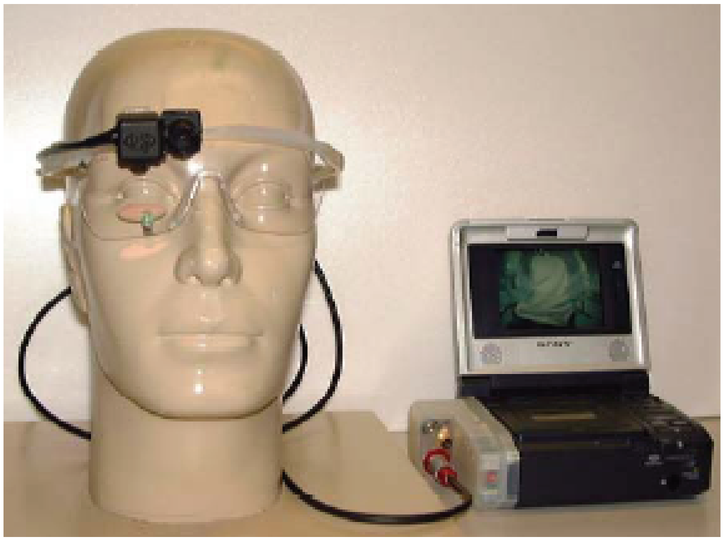

Figure 1. ASL MobileEye system.

## 2.4 Facilities

The study occurred in two different locations to broaden the environments studied to include possibly area-specific indicators, not to compare performance between the two locations. Both locations used 1.5-meter-wide by 15-meter-long mine lanes that contained mine simulants and clutter[1]. Some targets were removed from the ground at both locations (later referred to as ghost targets), thus leaving visual evidence of the action. The study occurred over the course of one day, so environmental changes were not an issue.

[1]Clutter is defined as non-mine targets (e.g., M16 brass, nails, wire) in the ground, which may be misconstrued by metal and mine detector operators as a mine.

The first two lanes bordered woodland terrain at the Fort Leonard Wood (FLW), Missouri, pole barn facility and were covered in tall, sparse grass with overhanging trees and shrubs. Each lane contained eight mine simulants, one for each of the eight mine sizes. The FLW mine simulants had been in the ground for 11 months by the time of the study.[2]

The remaining lanes were grassland terrain at Lincoln University's Land Mine Detection Center in Jefferson City, Missouri. The lanes were covered with relatively thick, short grass, with no trees or other obstructions. Each lane contained nine mine simulants, one for each mine size (as was contained in the FLW lanes) plus an additional Sim 6. The Lincoln mine simulants had been in the ground for 12 months by the time of the study, but a limited number of non-mine targets had been removed 1 week before the study. Weed killer had been sprayed around each 1.5-meter marker along the lane approximately 1 month before the study, which killed all the local vegetation and made the visual detection task more difficult near the markers.

### 2.5 Procedure

Upon completion of the volunteer agreement affidavit and the training survey, the participants were given an informal briefing about what they could expect to see. The briefing included some photographs of the ground over buried mine simulants (which were different from the mines used in this study) and a general description of the types of indicators that were present in the photographs. After the briefing, the participants were driven to the pole barn facility at FLW. They were given a description of how the MobileEye system worked and how they were to wear it and were then given a summary of the tasks they were being asked to complete.

Poker chips numbered 1 through 10 were laid in a grid fashion on the ground. The first participant donned the MobileEye, and a researcher adjusted the combiner (beam splitter) to properly reflect the eye and light. The participant then looked at each chip in turn for several seconds so that the video could be calibrated with the participant's gaze at a later time. Once calibration was complete, the participant walked to the first lane to begin visually searching for mines. The participant was not given any time limit to complete the lane. Each time the participant saw an area that appeared to have been disturbed (i.e., something was out of place), s/he indicated such, and a white poker chip was placed on the ground to mark the spot. The participant was asked why the specific area was chosen.

After the participant completed the lane, s/he returned to the beginning of the lane and was "graded". Blue chips were placed to mark the locations of clutter and removed targets that still showed disturbances. Red chips were placed to mark the locations of each mine. Correct mine declarations were recorded. Feedback was given about missed targets, especially mines, in order to facilitate the participant's learning of relevant indicators. Once the lane was graded, the participant moved to the second lane to begin the search process again. The second lane was graded in the same manner as the first.

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[2]The evidence of target removal had also weathered for 11 months, causing emplaced target locations and ghost target locations to look the same to pure visual detection.

The remaining participants followed the procedure just described. After all four participants completed the two FLW lanes, all went to Lincoln University to complete two more lanes. The same calibration, search, and grading procedures were used at the Lincoln lanes. Upon completion of the lanes for the study, all participants teamed to search a lane together to initiate a collective discussion and opinion about indicators. Each tracker pointed to the area(s) that s/he suspected as a mine in a given cell; all four discussed the reasons for choosing the area, and then a decision was made whether to mark the area. The cell was then graded, and general comments about the results were noted.

At FLW, the same two lanes were used for all participants. At Lincoln, given the equality of target dispersion and the uniformity of vegetation and terrain, different lanes were used for each participant's trials.

## 3. Results

Although not all mines in the FLW lanes were visually discernible to a single individual, participants as a whole were able to detect every mine simulant at FLW. In other words, each mine simulant at FLW gave some visual indicator that caused a tracker to mark it as a mine.

Since each participant ran different lanes at Lincoln, similar comparisons cannot be drawn for that site. However, when all four participants collaborated to informally search one lane together, the detection rate was 67%.

Three of the four participants walked down the first FLW lane once and then were graded as described in section 2.4. One participant, who had some difficulty understanding exactly what indicators to seek, walked through the lane once, marking only two targets, neither of which was a mine. The participant returned to the beginning of the lane, observed while two cells (one fifth of the lane) were graded and explanations about specific indicators were given, and then walked through the remaining eight cells (four-fifths of the lane) again, which were graded normally. The second FLW lane was completed by all four participants, as described in section 2.4, and the overall performance of the person who initially had trouble was indistinguishable from that of the other participants.

All four participants completed the Lincoln lanes as described in section 2.5.

### 3.1 Detection of Mines

The first FLW lane was the first time the participants had visually searched for land mines and received feedback about whether their declarations were correct. Trackers found 38% to 50% of the mines in the first FLW lane (see table 2). All participants improved in their second FLW lane, with Tracker 1 finding 75% of the mines in the lane. (Note: Because of the premature ending of a video tape, Tracker 3's second FLW lane data were not completely verified through the video as the other data were.)

Table 2.  Mine declarations (probability of detection).

| | **FLW Lanes** | | **Lincoln Lanes** | |
|---|---|---|---|---|
| | **First (percent)** | **Second (percent)** | **First (percent)** | **Second (percent)** |
| Tracker 1 | 38 | 75 | 44 | |
| Tracker 2 | 43 | 50 | 33 | 33 |
| Tracker 3 | 50 | *63* | 44 | 44 |
| Tracker 4 | 50 | 63 | 33 | 33 |

The grassy homogenous terrain of the Lincoln lanes made visual detection more difficult than it was at FLW.  Because of time constraints (the end of the day), Tracker 1 was not able to complete a second lane at Lincoln.  The other three participants maintained their probabilities of mine detection between the first and second lanes at Lincoln rather than improving between the first and second lanes as they did at FLW.

At FLW, the buried simulants were 50% AP and 50% AT.  Of all the simulants that participants identified at FLW, approximately 40% of them were AP mines and 60% were AT mines.  At Lincoln, the buried simulants were approximately 56% AP and 44% AT.  Of all the simulants that participants identified at Lincoln, approximately 35% were AP and 65% were AT.

The detectability of the different mine simulants by the four trackers is tallied in table 3.  The first number represents the number of times that particular simulant was found by all trackers, and the second number represents the number of times that simulant was encountered by all trackers (e.g., for the first lane at FLW, the four trackers found two of four Sim 6s).

Table 3.  Mine simulant detectability (by mine).

| | **FLW Lanes** | | **Lincoln Lanes*** | |
|---|---|---|---|---|
| **Target** | **First** | **Second** | **First** | **Second** |
| Sim 6 | 2 / 4 | 1 / 4 | 0 / 8 | 1 / 6 |
| Sim 9 | 1 / 4 | 3 / 4 | 1 / 4 | 1 / 4 |
| Sim 12 | 2 / 4 | 1 / 4 | 2 / 4 | 2 / 4 |
| Sim 20 | 1 / 4 | 3 / 4 | 2 / 4 | 3 / 4 |
| Sim 25 | 2 / 4 | 4 / 4 | 3 / 4 | 0 / 4 |
| Sim 30 | 2 / 4 | 4 / 4 | 2 / 4 | 2 / 4 |
| M15 | 3 / 4 | 1 / 4 | 3 / 4 | 0 / 4 |
| M16 | 1 / 4 | 3 / 4 | 1 / 4 | 0 / 4 |
| **Total** | **14 / 32** | **20 / 32** | **10 / 36** | **9 / 34** |

*Each lane for each participant was different.

## 3.2 Detection of Clutter and Ghost Targets

Participants were also given feedback about the clutter targets and ghost targets that they correctly marked as mine targets.  (The participants were not expected to differentiate between clutter and ghost targets and mine targets, nor did they do so.)  Each person marked anywhere from 3 to 13 clutter and ghost locations at FLW and from 1 to 8 ghost locations at Lincoln (see table 4).  (Recall

that ghost targets were the locations of targets that had previously been removed, leaving ground disturbances that were indistinguishable from those left by mine emplacement.)

Table 4. Number of clutter and ghost targets correctly declared as mine targets by participants.

| | FLW Lanes | | Lincoln Lanes | |
|---|---|---|---|---|
| | **First** | **Second** | **First** | **Second** |
| Tracker 1 | 6 | 7 | *8* | -- |
| Tracker 2 | 3 | 6 | 2 | 3 |
| Tracker 3 | 13 | *10* | 4 | 4 |
| Tracker 4 | 4 | 6 | 1 | 6 |
| Total | **26** | **29** | **15** | **13** |

The first FLW lane had 30 clutter and ghost target locations, and the second FLW lane had 32. One Lincoln lane (Tracker 4's first) had 30 clutter/ghost locations, and all other lanes had 15. Incidentally, for the high clutter lane that Tracker 4 encountered, only one actual clutter/ghost location was marked (3%). Time did not permit Tracker 1 to complete a second lane at Lincoln.

## 3.3 Non-target Declarations

Participants were encouraged to mark any area that they thought showed indications of mine emplacement. This understandably led to the marking of some areas that contained nothing, i.e., false alarms (see table 4). For the FLW lanes, Trackers 1, 2, and 3 decreased their false alarms from the first to the second lane, but Tracker 4 actually increased in the number of false alarms. For the Lincoln lanes, Trackers 3 and 4 maintained the same number of false alarms, while Tracker 2 only increased by one. (Recall that Tracker 1 did not complete a second lane at Lincoln because of time constraints.)

Table 5. Number of non-target declarations.

| | FLW Lanes | | Lincoln Lanes | |
|---|---|---|---|---|
| | **First** | **Second** | **First** | **Second** |
| Tracker 1 | 9 | 2 | *20* | |
| Tracker 2 | 5 | 3 | 6 | 7 |
| Tracker 3 | 32 | *12* | 23 | 23 |
| Tracker 4 | 5 | 8 | 12 | 12 |
| Total | **51** | **25** | **61** | **42** |

## 3.4 Comment Categories

Participants were instructed to provide verbal comments about why they chose to mark a particular area. These comments fell into several broad categories: natural anomalies, unnatural features, and unclassifiable feeling or "sixth sense". The tally of each comment category reported for correctly identified mine targets is shown in table 5. Table 6 lists the comment categories for non-targets (false alarms).

Table 6. Frequency of comments on why targets were marked.

| FLW Comments | | | |
|---|---|---|---|
| **No.** | **Category** | **Characteristic** | **No.** |
| 2 | 6th sense | unclassifiable | 2 |
| 6 | color change | natural anomaly | 30 |
| 9 | cracks | | |
| 12 | depression | | |
| 2 | ground change | | |
| 1 | mound | | |
| 4 | circular cracks | unnatural anomaly | 51 |
| 8 | circular pattern | | |
| 2 | disturbance | | |
| 8 | lack of vegetation | | |
| 14 | unnatural | | |
| 2 | unnatural ledge | | |
| 13 | unnatural stones | | |
| ***83*** | ***Total number of comments made*** | | |

Table 7. Frequency of comments on why non-targets were marked.

| FLW Comments | | | |
|---|---|---|---|
| **No.** | **Category** | **Characteristic** | **No.** |
| 1 | 6th sense | unclassifiable | 1 |
| 3 | color change | natural anomaly | 9 |
| 2 | cracks | | |
| 2 | depression | | |
| 2 | ground change | | |
| 0 | mound | | |
| 2 | circular cracks | unnatural anomaly | 26 |
| 3 | circular pattern | | |
| 3 | disturbance | | |
| 4 | lack of vegetation | | |
| 5 | unnatural | | |
| 2 | unnatural ledge | | |
| 7 | unnatural stones | | |
| ***36*** | ***Total number of comments made*** | | |

Tendencies shifted between FLW and Lincoln, but since the audio recording at Lincoln was mostly incoherent because of wind noise, only the comments written on site and the actions of the participants at Lincoln could be analyzed. Most of the comments made at the Lincoln lanes were circular patterns, differences in the density of vegetation, depressions, some surface cracking, and recurring plant species over targets.

## 3.5 MobileEye

A review of the eye tracking video provided some insight into the methodology that the participants used to evaluate the terrain for mine targets. A generic search pattern used by the partici-

pants focused on the lane within a few feet forward of where the participant was standing. The search proceeded with saccadic eye movement between areas of interest, such as areas devoid of vegetation. Each of these areas of interest was further inspected by visual scanning of the interior and perceived edges of the area to find cracks, determine circular shapes, or identify other indicators listed in this report. All participants continually used comparisons with the target area and the surrounding area as a basis for identifying potential mine targets.

# 4. Discussion

Most of the knowledge of land mine indicators that participants had at the outset of this study was provided by the authors through verbal discussions; this was accompanied by a few photographs of some rather nondescript mines. Participants were otherwise on their own to study the ground, draw from their experiences, and learn from the feedback provided during grading. They were encouraged to identify and comment upon any new indicators that they noticed.

## 4.1 Indicators

The mine simulant in figure 2 was buried in early August 2005. The picture was taken at the FLW site in mid-July 2006. Even after 11 months of weathering, indicators announcing the presence of a buried object were still very apparent. It was one of two targets that all four participants marked as a mine.

The target area in figure 2 is plainly devoid of vegetation. Larger, sub-strata stones can be seen throughout. The soil is mounded over the target, which has led to the development of cracks (unnatural for this particular area). The soil covering the target is a different color than the surrounding soil. Indicators observed on other targets were depressions, circular patterns and cracks in the soil, unnatural soil ledges and wash-outs, and general ground changes. Photographs of some of the mine indicators present at the FLW lanes are presented in appendix B.

If a comparison is made between the indicators given for actual target “hits” versus “false alarms,” it is possible to further distinguish which indicators have a stronger association to mines than to the non-target false alarms that were found in the lanes. In looking at the percentages of targets that were associated with each indicator, the most prevalent mine indicators were the presence of unnatural stones and an unnatural look to the ground. However, these two indicators were also the most prevalent in the false alarm descriptions. Common indicators that were much more prevalent for actual targets than false alarms were primarily cracks or depressions in the soil. Conversely, the appearance of a disturbance in an area of the ground was found to be much more prevalent with false alarms and was not a major indicator for actual targets.

Figure 2. Sim 30, approximately 11.8 inches in diameter, simulating an AT LM mine.

Indicators at the Lincoln site were similar to those at FLW, but the terrain change from FLW to Lincoln shifted the indicators that were prevalent: circular patterns and cracks, depressions, density and color of vegetation, and specific vegetation often found over targets. Photographs of the mine indicators present at the Lincoln lanes are shown in appendix B.

At the FLW site, a learning process was apparent with all trackers finding more targets in their second lane while generally decreasing their false alarm rate. However, with the difficult homogeneous terrain at the Lincoln site, almost no learning effect was observed.

## 4.2 Expected Values

The total area of each lane is 225,000 $cm^2$. Adding the area of the mine targets in each FLW lane yields a total area of 10,217 $cm^2$ where mine targets are located. The mine-covered area at the Lincoln lanes is 10,350 $cm^2$. It can then be assumed that any point picked randomly in the FLW and Lincoln lanes will have a probability of a target hit of 0.0454 and 0.0460, respectively. Thus, given the amount of chips placed by the participants, chance target identification should be a rare but possible occurrence.

## 4.3 Targets

AT mine simulants were easier to find than AP mine simulants but not overwhelmingly so. The participants involved were trackers, not land mine specialists, who were not familiar with the size

or shape of the targets in the ground. Although this made their work at identifying targets a bit more difficult, it was advantageous for obtaining objective target declarations and descriptions. The participants relied on their training in micro-tracking, looking for the minute details of disturbances and indicators of things that are out of place. They did not jump ahead, looking for what they expected to see or where they expected to see it, but instead, they methodically and logically determined what clues might indicate a target.

Participants were also able to identify the locations of clutter, as was discussed in section 3.2. Clutter could be a nail, a piece of wire, or whatever was handy, but it was always smaller than the land mines in the lane. Many of the clutter and ghost target locations at both sites were *not* visibly noticeable, even after the locations were pointed out to the participants. In fact, the locations at Lincoln were difficult to find, and all participants commented about it.

### 4.4 Vegetation

The density of vegetation strongly influenced visual detectability. The sparseness of vegetation at FLW allowed easy viewing of the soil itself, exposing tell-tale indicators such as sub-strata stones, discoloration, and depressions or mounds. Given the nature of the area, vegetation was slow to reestablish itself once disturbed, making it easier to see areas unnaturally bare of plants.

At Lincoln, where the vegetation was thick turf, two of the participants often used their hands to feel the underlying ground to find depressions or mounds. (Note: Participants were informed that tactile investigations would not be acceptable in live mined environments, but since this was a feasibility study, the practice was allowed with the thought that other indicators might be discovered with its use.) All participants focused on bare spots, but this was of more limited usefulness than at FLW since there were fewer spots and they were often obscured by the surrounding grass. Lincoln showed more discolorations in the vegetation. Upon closer inspection, some instances of discoloration were actually from the dried stems of clover (and potentially some other plants) that had died when the target was buried. When the clover regrew through the dead matter, the patch had a different shade and texture, denoting it as dissimilar from the surrounding vegetation.

It was also noted that oftentimes, a particular species of plant was found growing over targets (see figure 3). Although the plant species could be found in many places and was not in itself an indicator of disturbed ground, it was a secondary indicator that would often support other evidence for the presence of a target.

Figure 3. Common yellow oxalis, also known as yellow wood sorrel.

### 4.5 Lesson Learned

Three mine simulants were actually exposed to view. The first one had nearly the entire top and half of its side exposed. All participants saw the target, but two disregarded the sky blue simulant as trash, such as a soda can, and did not take a closer look before finishing (it was at the end of the lane).

The second visible mine was completely exposed on top in the soil but mostly covered by a large rock. A sliver of the top edge of the black simulant could be seen from the side. All participants noticed the rock, but only one thought it was out of place and used that indicator along with some other indicators (such as the unusual washing away of the ground and the presence of some sub-strata stones) to suspect it as a target.

The participants had adjusted and taken note of oddities in the lanes by the third visible target. The third visible mine had a thin, sky blue crescent of the top showing. The target was not easy to see unless the person looked from the correct angle, but three of the participants noted it and marked it as a mine.

The lesson learned is that when teaching the indicators and signs, one must place emphasis on not overlooking the obvious. Students must also be encouraged to use logic when considering multiple indicators that might not by themselves indicate a mine but when taken together are quite conclusive.

### 4.6 Limitations

One participant who normally wore prescription glasses did not do so for this study, thus marginally lowering the ability to detect targets. The authors were unable to obtain the participant's uncorrected visual acuity.

Participants searched for simulants, rather than unfuzed mines (land mines with the explosives but no fuzes to detonate the explosives). Although both types of targets leave similar indicators from emplacement, depending upon the care with which the simulants were buried, the long-term effects of the explosive and the mine case on the soil and vegetation are lost. Also lost are any detonating mechanisms such as trip wires or prongs that might be used on certain mines.

### 4.7 Conservative Probability of Detection

Researchers went to great lengths to disguise any indicators present when the simulants were buried at Lincoln. Efforts included tapping the simulant to settle the soil surrounding it, standing and stomping on top of the sod placed over the simulant to level it, and watering the grass throughout the summer to alleviate the stress on recovering vegetation. The net effect of these efforts was reduced visual indications of disturbances, which suggested that the probability of detection for this study at Lincoln was lower than what might be achieved in a live mine environment.

## 5. Recommendations

The authors recommend that combat engineers, visual trackers, and anyone who will be in possible land mine-contaminated areas receive training about visually locating land mines, including practical exercises. Such people should also be familiar with the characteristics of areas that are likely to be mined, how they are likely to be mined, and the effects that time and weather can have on the migration of those mines.

The authors further recommend that research be conducted to broaden the visual indicator knowledge base to encompass different terrains and environments, various burying methods, and seasonal changes. Studying the long-term effects of land mines on surrounding vegetation may provide additional visual indicators geared toward mines that have been in the ground for many years.

## 6. Conclusions

The objective of this study was to identify indicators that enable the visual location of buried land mines by the incorporation of the unique skills of trained trackers. Four visual combat trackers,

none of whom had ever conducted land mine detection, individually found at least 33% of mines with only visual detection. The performance of the trackers in locating buried mines, based on visual indicators alone, demonstrated that visual mine detection would be an excellent supplement to other mine detection methods. With further research and trained mine detectors (e.g., engineers or humanitarian de-miners), it has an even greater potential for locating buried mines.

Each mine simulant at the FLW site had some visual indicator that caused a tracker to mark it as a mine. Indicators included sub-strata stones, color changes, surface cracks, depressions, mounds, circular patterns (cracks, bare spots, vegetation, soil composition, etc.), disturbances, unnatural ledges or soil wash-outs, and recurring plant species over targets.

The primary skill needed for visual mine detection is the ability to discern what is natural for a given area and environment and what is not. Training visual land mine detection skills is recommended for combat engineers, visual trackers, and anyone who may be exposed to land mine-contaminated areas. Further research is also recommended to broaden the knowledge base of visual indicators to encompass different terrains and environments, various burying methods, and seasonal changes. As a direct result of this study, training visual land mine detection skills has already been implemented at the U.S. Army Combat Tracking School at Fort Huachuca, Arizona.

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## Appendix A. Apparatus and Materials

**Rank:** _____________ **Unit:** ________________________________ **Date:** / /2006

**Instructions:** Please answer the following questions about your previous experience with combat tracking and visual detection as completely as possible.

a. When did you complete your most recent visual tracking training?

Year: __________

b. Approximately how often do you practice your visual tracking skills? (Circle one.)

Once per day    Once per week    Once per month    Seldom

c. Have you ever been trained specifically to visually search for mines or IEDs? YES NO

   a. If yes, please describe (use the back of the paper, if necessary):

   ___________________________________________________________

d. Have you been trained in mine or IED detection (e.g. mine detector operator)? YES NO

   If yes,

   a. On what system or in what area were you trained?

   _______________________________________________________

   b. When were you trained? Year: ____________

   c. Were you trained to look for specific visual indicators? YES NO

      i. What were they? _____________________________________

      ____________________________________________________

   d. Have you ever used your mine detection training in countermine operations? YES NO

      i. If yes, approximately how many hours in theater did you operate?

      *Do not include training time.* Hours: ___________

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## Appendix B.  Fort Leonard Wood Mine Simulants

### FLW Mine Simulants

The following are photographs from training lanes for AN/PSS-14 mine detector operators at Fort Leonard Wood, Missouri.  Table B-1 summarizes the targets that were emplaced, along with miscellaneous clutter, in the lanes in early August 2005.  These photos were taken mid-morning on 17 July 2006.

Table B-1.  Targets emplaced in August 2005

| Mine Simulant | Diameter (inches) | Simulant Type |
|---|---|---|
| Sim 6 | 2.36 | |
| Sim 9 | 3.54 | APLM |
| Sim 12 | 4.72 | |
| M15 | 12.5 | ATM |
| M16 | 3.00 | APM |
| Sim 20 | 7.87 | |
| Sim 25 | 9.84 | ATLM |
| Sim 30 | 11.81 | |

I3 – M15 had 3 hits.  Note the circular bare spot and some faint pressure cracks.  The small pebbles are not completely unnatural for this particular area but are noteworthy.

J4 – Sim 25 was obvious with a pronounced color change at the time of the study.  Something has scratched around in the depression, disturbing what would have been a good example.

J4 – All 4 participants marked this target.  Note the semi-circular ledge above this depression… also some larger stones dredged from an under layer of soil during (human) digging.

J4 – There are some pressure cracks that may not have been present before (the soil dried between the time of the study and the time the photograph was taken).

J7 – Sim 9 had 3 hits.  The circular bare spot is noticeable.  The blue crescent giving away the simulant's location was difficult to see unless observed from the proper angle.

J7 – The tan rock in this photograph is directly above the blue crescent in the previous photo. (The two chips were removed for this photo.) Notice the semi-circular ledge on the top side of this area.

J8 – Sim 30 had 4 hits. This target was not buried very well; it has a slight mound in a generally depressed area, with strong pressure cracks across the mound. The area also has a distinct lack of vegetation.

J8 – The color change is faintly shown on the mound here with some larger stones.

## Lincoln Mine Simulants

15-2 – Sim 12.

15-2 – Sim 12.  Bare circular pattern.

15-8 – Sim 20.

15-8 – Sim 20.  Depression, bare spot, some wood sorrel, dead vegetation, ant hill.

15-9 – Sim 6.

15-9 – Sim 6.  Circular green pattern.

17-5 – Sim 25.

17-5 – Sim 25.  Slight bare spot, wood sorrel, ant hill.

19-4 – M15.

19-4 – M15.  Slight bare spot, circular pattern, depression, wood sorrel, ant hill.

19-7 – Sim 30.

19-7 – Sim 30.  Depression, wood sorrel, dead leaves. (crab grass.)

19-8 – Sim 12.

19-8 – Sim 12.  Circular bare spot.

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